A METHOD FOR DEFINING THE LOCATION AND THE EQUIVALENT FLAW SIZE OF DEFECTS IN NON-DESTRUCTIVE MATERIAL TESTING BY ULTRASONIC ECHO PULSES

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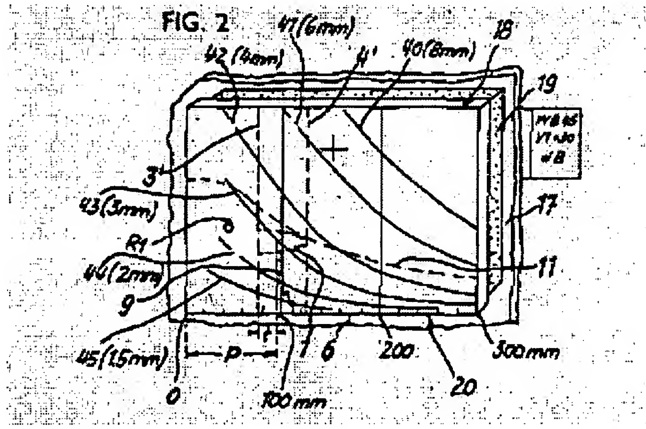
Abstract of **GB1239970**

1,239,970. Ultrasonic inspection devices. DR. J.U.H. KRAUTKRAMER GES. FUR ELEKTROPHYSIK. 5 July, 1968 [31 Oct., 1967], No. 32146/68. Heading H4D. In an ultrasonic pulse-echo inspection method for evaluating the magnitude of test specimen defects in terms of the size of equivalent disc- shaped reference flaws, and for locating defect positions, a cathode-ray tube (C.R.T.) provides an echo display, a transparent graph bearing a time-base scale and also DGS curves relating the echo amplitudes of such reference flaws to their sizes S and their distances D from a trans- ducer probe is placed in front of the C.R.T. screen, the gain G of the ultrasonic inspection apparatus is first adjusted to bring the height of a displayed echo from a reference reflector block to a predetermined mark on the graph and secondly is raised a predetermined amount necessary for setting correct the heights of test specimen echoes in relation to the echo heights of said reference flaws on the curves, the equiva- lent flaw size of a test specimen defect is then determined from whichever curve is just reached by the peak of the displayed defect echo, and the defect position is determined from the position of its echo on the time-base scale. In the Fig. 2 embodiment plastics sheet 18 bears echo amplitude/distance (DGS) curves 40, 41 . . . 45 for reference flaws of 8, 6. . . 1Å5 mm. diameter in a particular material. Plastics sheet 19 bears a distance scale 6 oriented along the C.R.T. time-base. R1 is a reference mark representing the height of the back-wall echo from a reference reflector block (approximating an infinite reflector), but plotted 30 dB below its true position. To calibrate the apparatus for testing,

FIG. 2



the gain is adjusted to bring this back-wall echo up to R1, then is increased by 30 dB. The slopes of the DGS curves may be altered to take into account the ultrasonic attenuation of different test materials, and a curve 11 for an assumed attenuation-free material may be drawn for evaluating gain corrections to take into account losses by roughness and curvature of a test specimen.

PATENT SPECIFICATION

(11) 1 239 970

DRAWINGS ATTACHED

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1 239 970

(54) A METHOD FOR DEFINING THE LOCATION AND THE EQUIVALENT FLAW SIZE OF DEFECTS IN NON-DESTRUCTIVE MATERIAL TESTING BY ULTRASONIC ECHO PULSES

(71) We, DR. J.u.H. KRAUTKRÄMER, GESELLSCHAFT FÜR ELEKTROPHYSIK, of 449 Luxemburger Strasse, 5 Köln-Klettenberg, Germany, a German Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to a spatial scale arrangement in front of the screen of a pulse-echo apparatus for ultrasonic testing of materials by aid of which defining of the location and the equivalent flaw size of a defective spot in for example, a welding seam is facilitated. According to German Patent 1,108,477 it is known in ultrasonic materials testing by the echo method to signify a defect by a circular disc-shaped equivalent flaw, which is located equally distant from the scanning site, and which delivers an echo equal in height to that of the defect, otherwise being subject to identical conditions. In the remote field of the probe, which theoretically can easily be examined, a formula can serve for demonstrating the inter-relations between the circular disc defect area and the probe data, as well as between the echo sound pressure and the average sound pressure immediately in front of the probe when transmitting. The last mentioned value is obtained in the form of a reference echo which is the rear echo of a plate having a small thickness only when compared with the near-field length.

According to known art (Refer to "Determination of the Size of Defects by the Ultrasonic Pulse Echo Method", by Krautkramer, British Journal of Applied Physics, vol. 10, June 1959, pages 240 through 245; Training Book for ultrasonically Testing by Krautkramer Ultrasonics Inc., Stratford, Conn., Oct. 1962; The Echo, No. 18, May 1967, pages 164 through 166, Krautkramer information on non-destructive testing with ultrasound), the effective flaw size is determinable by aid of a diagram, in which are entered the flaw distance A(D) from the probe, as abscissa, the gain value V(G) of the testing apparatus as ordinate, and the flaw size G(S) as a further parameter. A circular disc shaped reflector with its plane normal to the direction of the sound beam is presumed as a reference defect. Since the sound pressure diminishes with distance, due to the divergence of the sound beam in the remote field, and the attenuation in the material, the echo amplitude will decrease with increasing reflector/probe distance if gain is maintained at a constant value when relating the amplitude to the distance. The A.V.G. diagram represents a reference curve or curves. For a small reflector the difference between the amplitude height of the small reflector and that of an indefinitely large reflector—both equally distant from the probe—represents a measure for the size of the small reflector.

The determination of flaw location in weld testing by aid of a graduated body, such as a graduated disc in front of the CRT screen has been described by W. H. Papke (Proposal for documentary recording of ultrasonic weld testing results, Schweissen und Schneiden, Vol. 13 (1961) pages 457 through 463). For that purpose the horizontal time base scale of the graduated disc is calibrated in units of length, representing the so called distance of projection, i.e. the sound path length from the probe to the reflector surface projected onto the sheet metal surface. Because of practical reasons it is not measured from the sound emission point of the probe, but from the leading edge of the (mostly rectangular) probe, to which a measuring rule, e.g. a tape measure can easily be touched for measuring of the flaw location on the sheet metal. For a defect vertically below the leading edge of the probe the thus defined

[*Price 25p*]

distance of projection consequently amounts to zero.

According to the above method of Papke the cross-section of a welding seam is depicted in such a graduated scale, thus establishing the flaw depth location in the weld by the intersection of the echo ascent shoulder with the axis of symmetry of the cross-section, and the lateral flaw location in the weld by transferring the distance of projection onto the sheet metal. A schematic embodiment of the invention is demonstrated by means of the drawings, Figures 2, 4 and 6 of which illustrate an embodiment of the invention.

In these drawings:—

Figure 1*a* is a side view of the specimen metal sheet with a probe and welding seam cross-section, and a block diagram of the electronic measuring apparatus;

Figure 1*b* is a CRT screen display related to Figure 1*a* with e.g. a drawn-in weld shape;

Figure 2 is a spatial scale arrangement with localising scale, AVG (DGS) scale, and CRT screen;

Figure 3 is a calibrating set-up pertaining to Figure 2;

Figure 4 is a scale arrangement for a variation, corresponding to that shown in Figure 2, which is however simplified;

Figure 5 shows a test arrangement.

Figure 6 is a simplified illustration of a further scale arrangement.

Figure 1 presents a "tulip weld" in a metal sheet 2 of thickness *d*, with top and bottom faces 3, and 4 respectively. The welding seam symmetrical to line 5 contains a defect 6 in depth location *t* from the top face 3. An angle-beam probe 7 scans from position *a* the upper weld region (in one skip distance), and from point *b* the lower region (1/2 skip distance).

According to the basic laws of trigonometry the flaw co-ordinates, distance of projection P, and depth location *t* are correlated as follows:

(1) $$t = \frac{P + E}{\tan \alpha}$$ if the probe 7 of Figure 1*a* is moved from position *b* in direction of weld cross-section 5

(2) $$t = 2d - \frac{P + E}{\tan \alpha}$$ in the shifting range between *a* and *b*, and

(3) $$t = \frac{P + E}{\tan \alpha} \sin (1/2 - v)\pi + d\,(v + \sin^2 v\frac{\pi}{2}) \sin (v - 1)\frac{\pi}{2}$$

in general, where t = depth location, from the top face of the metal sheet

P = distance of the defect 6 from the probe leading edge in direction parallel to the metal sheet,

E = distance from the emission point of the sound beam axis of the probe to the leading edge,

α = angle between sound beam axis and normal on 3,

v = 0, 1, 2, 3, ... corresponding to various multiples of a half "skip distance" (Figure 1*a*), from 5 towards the left (i.e. v = 0 till probe position *b*, v = 1 between position *b* and *a*, and so on).

The pulser supplies probe 7 with a high tension pulse, which is converted into an ultrasonic pulse in the probe 7. The ultrasonic pulse returned by a reflector to the probe 7 again is converted into an electrical pulse. It is amplified in the receiver and the video amplifier so that the deflection plates 29 and 26, which are connected with the video amplifier through leads 22 and 32, deflect the electron beam of the CRT 23 vertically. The clock triggers the pulser for high voltage pulse generation in preselected time intervals, and synchronously starts the sweep delay, which is connected with plates 27 and 33 through cables 21 and 28. The sweep delay generates a saw tooth voltage deflecting the electron beam horizontally. The deflection period corresponds to the transit time of the sound beam in the specimen 2. The CRT screen presents the display. The initial transmitter pulse, which arrives at the receiver via the path traced on the drawing appears at the left as 25, where the zero point of the time base 31 is set. A flaw echo appears at a point proportional to the distance from the probe, provided the time base calibration is accurate.

Figure 1*b* presents a CRT screen display of a weld defect with initial pulse 8, and flaw indication 9. If the time base 10 is calibrated in projection distances P according to the well known method, the sheet metal cross-section can either be entered on the CRT screen, as in Figure 1*b* or be projected thereon, according to equation (3) for v = 1, i.e. shifting of the probe between the positions *a* and *b* in accordance with Figure 1*a*. The lower metal sheet face 4 appears according to equation (3) in a defined distance P at a position corresponding to *t* = *d*, and the top face 3 at a position corresponding to *t* = *O*. The echo indication 9 of the defect 6 appears consequently within the

e.g. drawn-in cross-section of the metal sheet. Both defect co-ordinates can be read off without difficulties. For a larger or smaller v-value the metal sheet cross-section is folded around the line 3′ or 4′, as implied by equation (3).

In practical application sometimes the time base (X axis) of the CRT screen display is calibrated in values of sound path distance. For the scales this means a standardisation, since the contents of the scales then are valid for all scanning angles, provided the geometric and electric characteristics of the electro-mchanical transducer are not changed. The invention may therefore be carried out by the use of scales, the abscissas of which are calibrated in values of sound path distance.

According to another embodiment of the invention a surface fraction of the AVG (DGS) diagram is entered in such a graduated scale, or the graduated scale and the AVG (DGS) diagram are independently drafted, in such a manner that the backwall echo amplitudes of a reference block, i.e. amplitudes of the curve for an echo returned by a very large plane, vertically scanned reflector, are plotted at an amplifier gain reduced by a fixed value e.g. 30 dB, relative to the gain for the A.V.G. diagram.

Figure 2 shows such a compiled scale arrangement for a certain angle-beam probe (type designation WB 45, scanning angle 45°), and a certain pulse-echo apparatus with CRT screen 17. The representation of 1 of the welding seam can be easily erasable on the graduated sheet, e.g. drawn with a tallow pencil on translucent plastics, since it is valid for a predetermined shape of weld and thickness of metal sheet only. A separate primary AVG (DGS) scale body 18 may, however, be existent, onto or underneath of which the localising scale body 19, e.g. a thin plastics foil, is attached such as pressed against, or pasted, and which is equipped with a length scale portion. In the example a cross-section of a metal sheet of 50 mm thickness appears with the top face at 3′ and the lower face 4′, if testing is intended to be performed between 2/2 and 3/2 skip distances (v=2 in (3)). The scale itself, for practical reasons, is drawn on the reverse side of the plastics in order to increase the reading accuracy and the erasive resistance. The abscissa defines the projection distance P of a reflector, measured from the leading edge of the probe.

For example a flaw echo 9 returning from about the half metal sheet thickness is entered in the CRT screen display, which is visible through the graduated sheet. The uninterrupted lines 40—45, descending from left to right represent the distance dependence of the reference echo amplitudes of various circular disc-shaped equivalent flaw diameters. They are taken from the AVG (DGS) diagram. The arabic figures entered in the interrupted line sections indicate the size of the equivalent disc-shaped defect. The flaw echo 9 returning from the weld just reaches the 3 mm line, the defect consequently has an equivalent flaw diameter of 3 mm. A condition for accurate size determination is the previous setting of the apparatus gain for example by aid of the cylinder backwall echo from the reference block according to DIN 54 120 (German Industrial Standard 54 120) (Figure 3).

By changing the apparatus gain the echo of the cylinder area 12 (Fig. 3) of 100 mm radius is moved into the centre of the circle designated R_1 in Fig. 2. Figure 4 once again shows the graduated sheet with the echo 13 from cylinder area 12 (dotted line) visible on the CRT screen. If the gain is increased by the amount in dB, in this case by 30 dB which is represented vertically on the grudated sheet, the apparatus is accurately calibrated for flaw size determination.

Further, the shape of the echo pulse height curves for the predetermined flaws may be altered to take account of the attenuation of the sound energy for a particular specimen material under test at a certain predetermined frequency. This attenuation to be taken account of is an average of 60 dB/m for an ultrasonic frequency of 4MM2 which is the average value of attenuation in a particular material. With this correction the echo height curves descend more steeply with distance, and understanding of the flaw size is avoided by this effect.

This embodiment of the invention further provides for the entering of the backwall echo curve 11 on the graduated sheet (dashed line in Figures 2, 4 and 6), as would be obtained for an attenuation-free material from the AVG (DGS) diagram. This curve serves, for establishing a correction value of the gain, in order to take into consideration the losses by roughness and curvature of the specimen. For assessing a reflector dimension perpendicular to the probe scanning direction the probe may be shifted to the left and right perpendicularly in relation to its scanning direction, i.e. parallel to the reflector, until the echo height at the left, as well as at the right is equal to the height of the value obtained prior to a 20dB gain increase made at a central probe position. The pertaining shifting of the probe *c* in Figure 6 is read off. Measuring of *c*, is no longer in terms of the distance or projection P, but in terms of the sound path. The length of the sound path is

$$\frac{P}{\sin\alpha}$$

An individual scale can be indicated for the sound path (not drawn).

If employing an extremely narrow, cylinder sound beam, *c* would equal the length of the reflector. If employing a diverging sound beam

which has an angle of spread in the remote field, the sound beam width must be allowed for in assessing the size of a small reflector.

WHAT WE CLAIM IS:—

1. A method for defining the location and the equivalent flaw size of defects in non-destructive material testing by ultrasonic echo pulses comprising the steps of, providing a transparent graph having placed thereon at least one abscissa scale and curves relating the echo heights of different predetermined sized flaws to the flaw distances from a transducer probe, said curves being obtained from a relationship according to which the echo amplitude decreases with increasing distance and decreasing diameters of circular disc reflectors used as equivalent flaw sizes, orienting said scale of the graph in front of the screen of a cathode ray tube forming the display tube for displaying the pulse echoes of the testing apparatus, in the direction of the time base of the cathode ray tube for indicating flaw distances, adjusting the gain of the testing apparatus to raise the amplitude of a displayed reference echo from a prescribed reflector test block to the level of a predetermined mark on the graph, the position of said mark being obtained from said relationship, on the graph, increasing the gain of the testing apparatus by a predetermined value which is necessary for setting correct the amplitude of test specimen, defect echoes in relation to the echo heights of said predetermined flaws on said curves, determining the position of a test specimen from the position of its echo on said abscissa scale and determining the equivalent flaw size of the defect from one of said curves just reached by the peak of the displayed amplitude of said echo.

2. The method according to claim 1 including the step of, providing on the graph as said predetermined mark the curve relating the echo height of the plane backwall of a specimen to the specimen thickness.

3. The method according to claim 1 including the step of correcting the flaw echo pulse height curves for the predetermined flaws to take account of the attenuation of the sound energy for a particular specimen material under test at a certain predetermined ultrasonic frequency.

MARKS & CLERK,
Chartered Patent Agents,
Agents for the Applicants.

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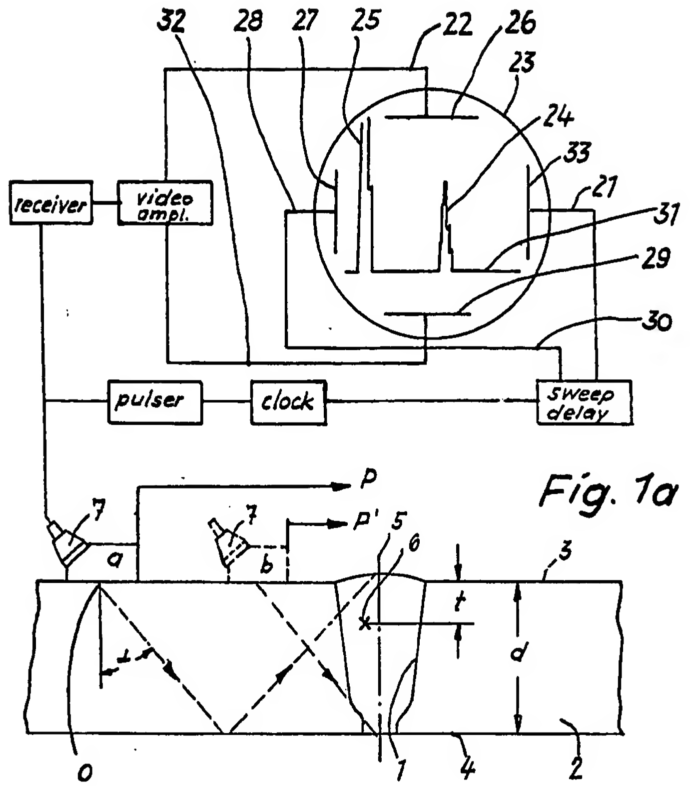
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video ampl.
pulser
clock
sweep delay
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2

Fig. 1a

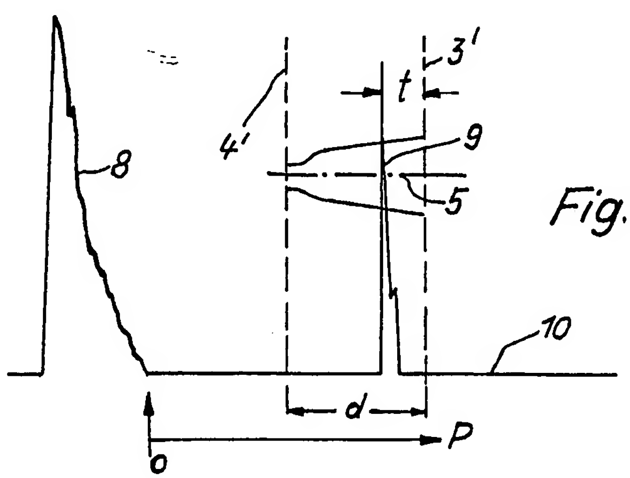
8
4'
3'
t
9
5
10
d
o
P

Fig. 1b

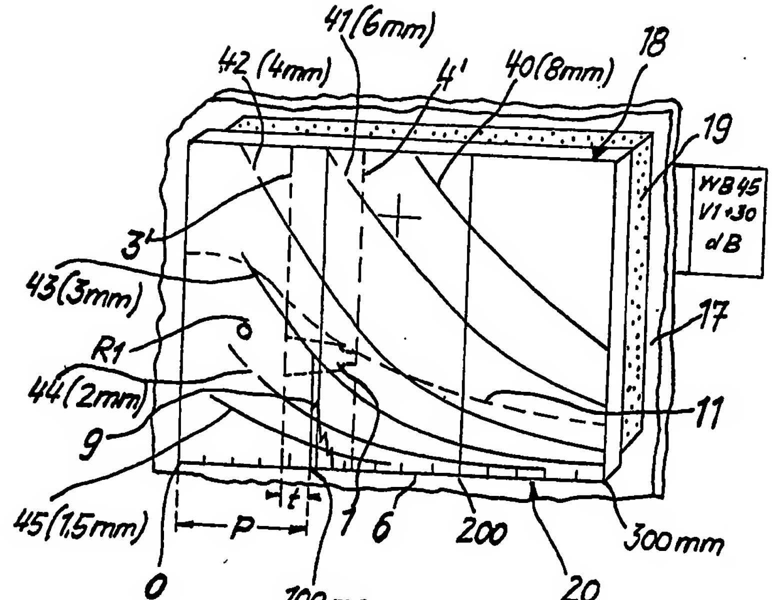
41(6mm)
42 (4mm)
4'
40(8mm)
18
19
WB45
V1+30
dB
3'
43(3mm)
R1
44(2mm)
9
17
11
45(1,5mm)
t
P
1
6
200
300mm
0
100mm
20

Fig. 2

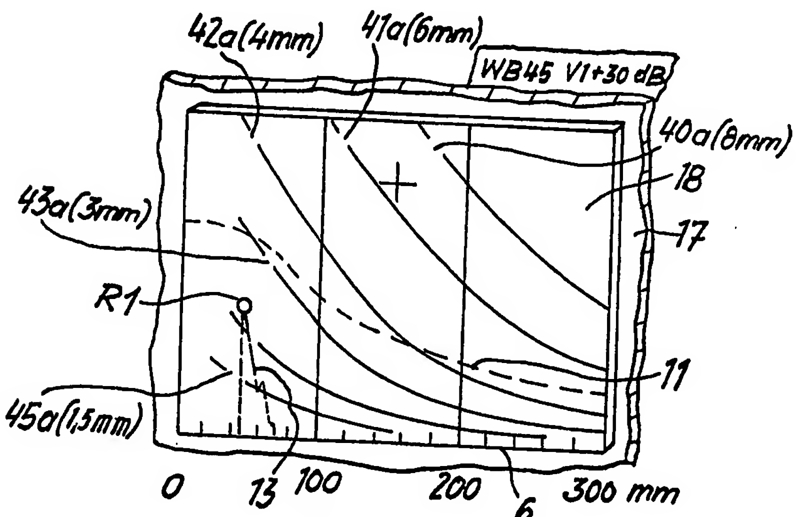
42a(4mm)
41a(6mm)
WB45 V1+30 dB
40a(8mm)
18
17
43a(3mm)
R1
11
45a(1,5mm)
0
13
100
200
6
300 mm

Fig. 4

1239970 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 3

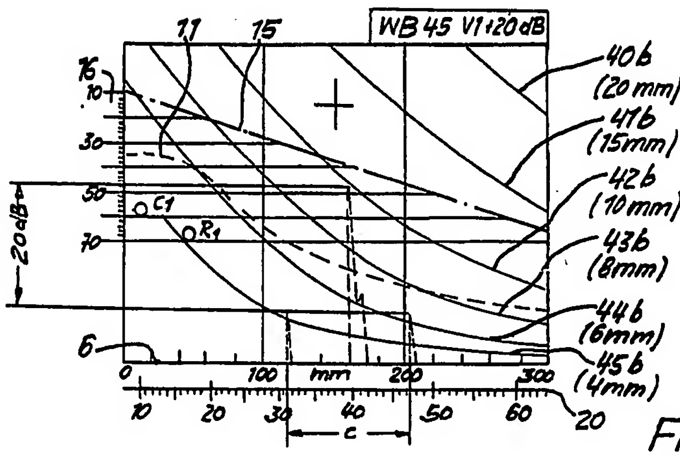

Fig. 6

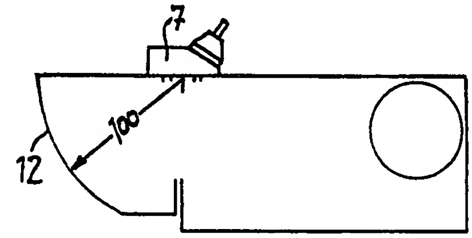

Fig. 3

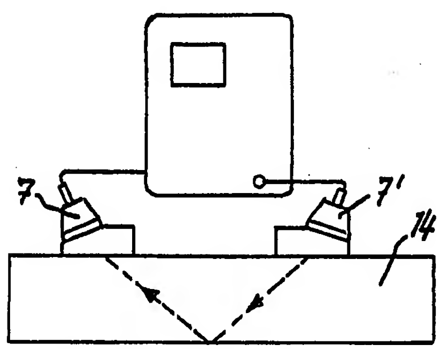

Fig. 5